Investigation into an explosion at the Wessex Water Avonmouth Sewage Treatment Works 3rd December 2020 and the Potential for Further Explosion Risks

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TRIDENT H&S

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1. Executive Summary

This report investigates the fatal explosion at Wessex Water's Avonmouth Sewage Treatment Works on 3rd December 2020, which claimed four lives. The explosion occurred in a biosolids storage silo constructed between 2003 and 2005. The plant processed dewatered, lime-stabilised sewage sludge.

The report contends that the incident was entirely foreseeable and therefore preventable. It suggests that there were significant deficiencies in risk assessment, silo design (lack of protective measures such as explosion relief panels), non-compliance with legislation and failure to by the Company to implement recognised British and European safety standards.

The report provides an evidence-based account of the factors most likely to have triggered the devastating explosion i.e.:

- An accumulation of methane gas within the silo (and explains how it may have come to be present there); and
- the source of ignition (likely to have been hot work using a disk cutter, though other possibilities are considered)

Management failures are discussed, most notably the lack of suitable risk assessments. The report explains the background rationale for risk assessment and describes a risk assessment methodology that is widely used in the water industry which, had it been applied to the plant at Avonmouth would surely have led to a recognition of the contributory factors which caused the explosion and enabled simple preventative measures to be put in place.

The report identifies a crucial moment in time (2007) where Wessex Water did, in fact, recognise the potential for explosions to occur in silos which contain biosolids and accepted the need for explosion relief panels to be provided. Questions have to be asked as to why the Company failed to take any action to retrofit such panels into the silos that were to be involved in the explosion some 13 years later. This was an opportunity missed and, on the face of it, confers corporate culpability for the deaths.

The report outlines the requirements of applicable legislation (Health and Safety at Work etc Act 1974 and the Dangerous Substances and Explosive Atmospheres Regulations 2002) and identifies the relevant breaches.

Further investigations led the author to suspect that there are other biosolids silos still operational on the site today which may be at risk of explosions. He considers this to be due to a fundamental flaw in the design of those silos which, again, can be traced back to a failure to properly assess risks. It is hoped that the Health and Safety Executive (HSE) will have identified this issue themselves during their inspections of the sludge handling plant following the 2020 tragedy and forced the Company to institute remedial measures. If not, this needs to be addressed as a matter of urgency.

The author critically calls into question the inordinate length of time that HSE has taken to publish the report of their investigations (5 years) and considers the impact of these delays on the bereaved families, friends and workmates of the deceased.

Whilst accepting that HSE are unlikely to publish the report of their investigation in advance of any prosecution they may may bring against Wessex Water, it is difficult to understand why this is taking them so long. Based on a statement by HSE's Principal Inspector in July 2024, after almost 4 years of investigation, the HSE appeared not to have even established whether any health and safety laws had been broken. This leads to the conclusion, in the author's opinion, that this once well-respected regulatory and enforcement agency is no longer fit for purpose.

2. Introduction

2.1. Purpose of this report

Five years have elapsed since the tragic incident† at Wessex Water's Avonmouth sewage treatment works which resulted in the loss of four lives. The Health and Safety Executive has had **five years** in which to investigate the cause of the incident, conduct any prosecutions which may be appropriate and publish a report of their investigation. It is outrageous and inexcusable that the bereaved families are still waiting for a detailed explanation as to what caused the explosion, without which they cannot begin to find closure.

As an independent health and safety consultant, the author therefore decided to conduct his own investigation into the incident. It is hoped that this report may help to start filling the knowledge gap left by HSE's tardiness. It may also serve as a baseline against which the HSE's own report and their evidential submissions to Court can be critically reviewed.

† It should be noted that the word 'incident' is used intentionally, as opposed to 'accident'. There are many ways in which 'accident' can be defined, including '*an **unforeseen**, unplanned, unintended, normally unwanted event that causes death or injury to people, damage to property or a combination of both*'. There is no doubt that the events of 3 December 2020 were not planned or intended, and most certainly not wanted. However, as will become clear in this report, it is contended that the event was entirely foreseeable. It could, and should, have been prevented. The facts outlined in section 5.2 suggest that Wessex Water did, in fact, foresee that an explosion could occur in such silos some 13 years before the incident but failed to put measures in place which may have prevented or mitigated it.

During the investigation prima-facie evidence was discovered which suggests a possible risk of explosion in other silos currently still in operation at the site. If Wessex Water and the HSE has done their jobs properly this will not be the case and the issues identified in section 5 below will have been identified and appropriate mitigations implemented. The HSE has been alerted to these concerns.

2.2. Author's Background

The author was Head of Safety and Security for Wessex Water between December 1994 and July 2000. Earlier in his career he was a Water Quality Officer exercising a regulatory/enforcement role in connection with river pollution and trade effluent control. He has a scientific background with a degree in biochemistry from Bristol University where he also studied microbiology. His career with Wessex Water gave him a reasonable understanding of sludge treatment processes and the risks associated with them.

In the interests of full disclosure, for several years in the late seventies through to the early eighties, he was based in the offices at Avonmouth Sewage Treatment Works, where he was friendly with the late Brian Vickery and Genevieve Custance (later to become Mrs Vickery). This report has been prepared in Brian's memory and the other 3 victims.

2.3. Limitations

This report will not discuss any matters relating to the author's time working for Wessex Water as there are legal reasons which preclude this. During their investigation into potential manslaughter offences, the Police took a statement from him and, even though the Police/Crown Prosecution Service have discontinued their involvement with the case, the statement has been passed on to the HSE and may be adduced into evidence in any criminal proceedings they might institute.

2.4. Investigation Methodology

The author has carried out his investigations into the events leading up to the fatal explosion solely by examining documents and other evidence available in the public domain from online sources. He has not been to the Avonmouth site since leaving Wessex Water in 2001. Neither has he sought information from anyone in Wessex Water.

Clearly, therefore, a certain amount of supposition has had to be involved in the preparation of this report and it should be read in that light. The author believes that he has made a reasonable interpretation of the facts, but willingly stands to be corrected should Wessex Water or HSE wish to point out any facts which are incorrect.

3. Avonmouth Sewage Treatment Works – Site Layout

The following images of the site layout are offered in order to provide context for matters to be discussed in this report (Source acknowledgement: Google Earth, 19 July 2024:

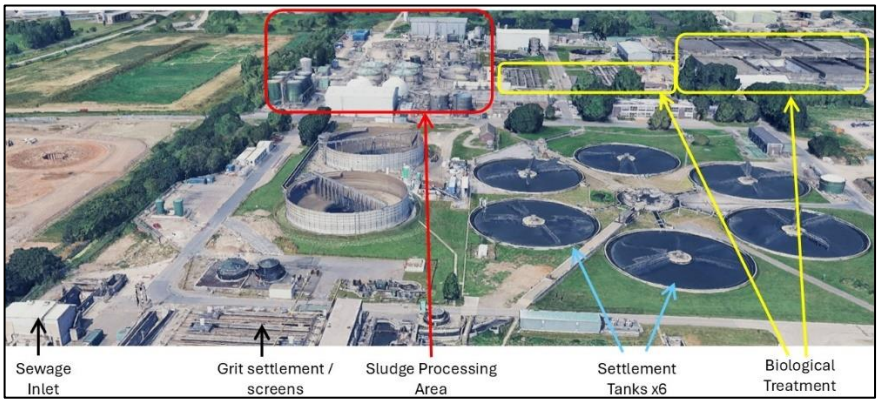

Fig 1: Overall Site Layout

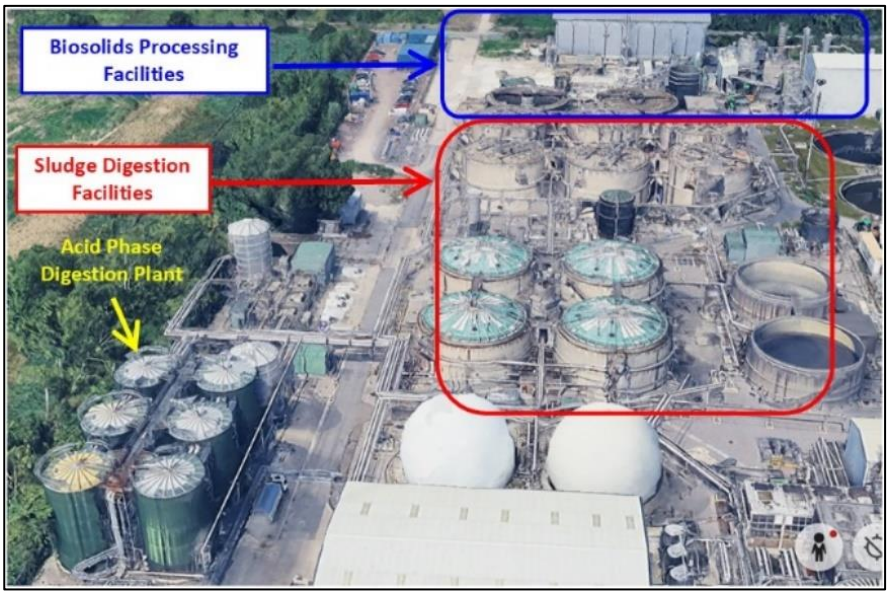

Fig 2: Sludge Processing Area

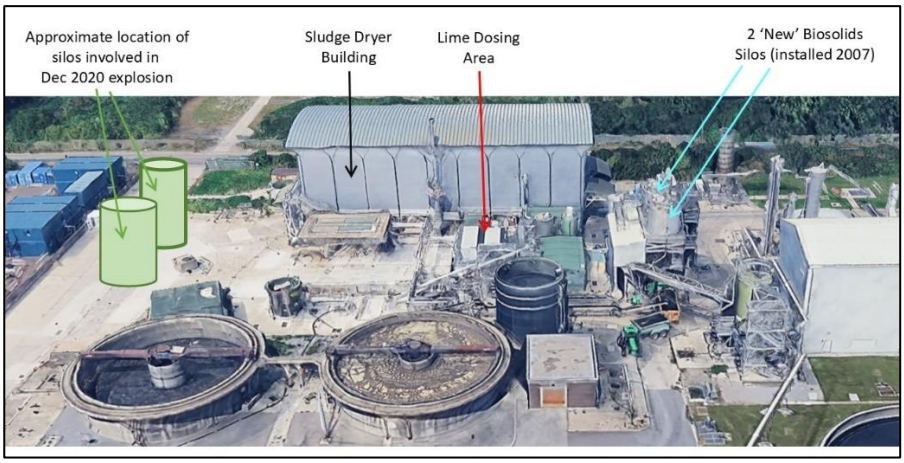
Approximate location of silos involved in Dec 2020 explosion
Sludge Dryer Building
Lime Dosing Area
2 'New' Biosolids Silos (installed 2007)

Fig 3: Biosolids Processing Area

4. Plant involved in the fatal December 2020 explosion

4.1. Installation Timeline

The two green silos contained de-watered, treated sewage sludge. They were constructed at some time between 31 Dec 2003 and 17 Apr 2005 (source Google Earth, historical imagery : figures 4 and 5 below). This timeline therefore puts this plant within scope for investigation in line with section 2.3 above.

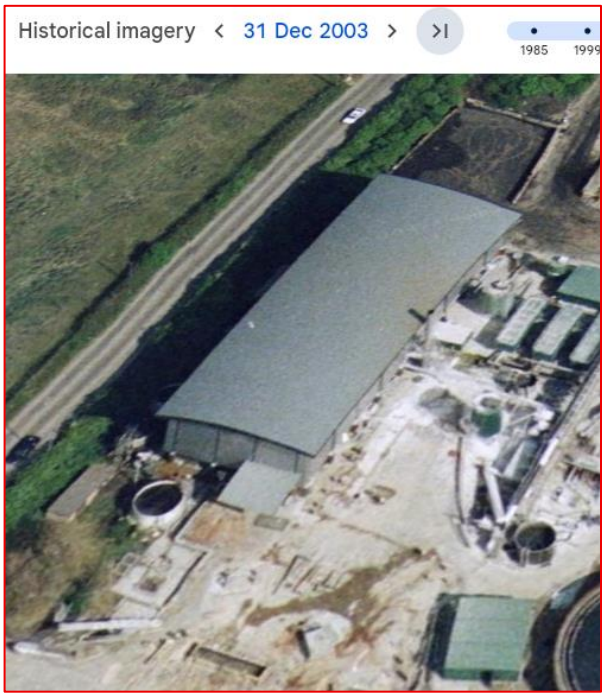

Fig 4: Site at 31 Dec 2003 (before construction of silos)

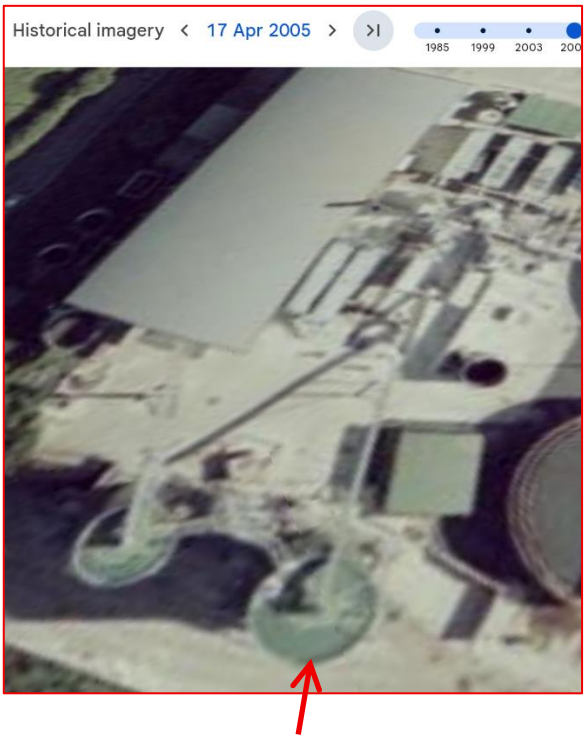

Fig 5: Site at 17 Apr 2005 Silo subject to explosion in 2020

4.2. Process

It is understood that the sludge treatment plant associated with these silos involves dewatering digested sludge and treating it with lime† to stabilise it, killing off the pathogenic (harmful) microorganisms present in sewage.

†The use of lime was confirmed by the Fire Officer in charge of the Dec 2020 incident in his press interview[1]. Although the exact configuration and nature of plant at the Avonmouth site is not known, it will most likely follow the general principles set out in figure 6 below:

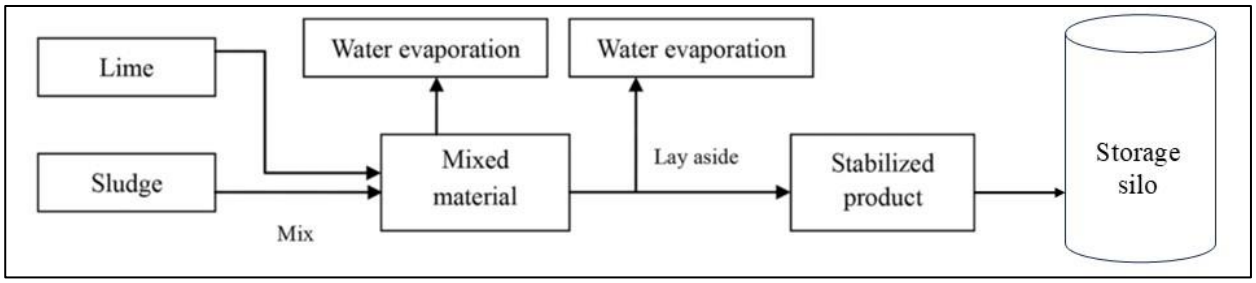

Fig 6: Generic process flow-chart of sewage sludge lime stabilisation[2]

[1] Interview with Fire Officer, 3 December 2020 - URL Link

[2] Novel approach on reduction in GHG emissions from sludge lime stabilization - Hongtao Liu 8 Nov 2018 URL Link

4.3. Risk Assessment

Since 1992 it has been an absolute legal requirement that employers make a 'suitable and sufficient' assessment of the risks to the health and safety of their employees and other persons who may be affected by the conduct of their undertaking.

Within a few days of the incident it became immediately apparent that Wessex Water had not complied with this requirement since the HSE served a prohibition notice against it as shown in figure 7 below:

Notice 311296273 served against Wessex Water Services Limited on 09/12/2020	
Notice Type	Immediate Prohibition Notice
Description	IN 311296628- No suitable and sufficient assessment of the fire and explosion risks arising from the dangerous substances produced, processed or used on site. PN 311296273 - No suitable and sufficient measure to eliminate or reduce risk of fire and explosion associated with hot work and maintenance processes that involve the application of heat or generation of sparks. Documentation does not adequately identify where explosive atmospheres are present or are liable to be present.

Notice	Breach ID	Recipient's Name	Act or Regulation
311296273	001	Wessex Water Services Limited	Health and Safety At Work Act 1974 / 2 / 1
311296273	002	Wessex Water Services Limited	Health and Safety At Work Act 1974 / 3 / 1
311296273	003	Wessex Water Services Limited	Dangerous Substances and Explosive Atmospheres Regs 2002 / 6 / 1

Fig 7: Prohibition Notice served by HSE on Wessex Water[3]

The breaches of legislation relate to sections 2 and 3 of the Health and Safety at Work etc Act 1974 (HASAWA) which establish the statutory duty of care to employees and third parties and regulation 6 of the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) which requires employers to eliminate or reduce risks from dangerous substances so far as is reasonably practicable.

4.4. Likely cause of explosion

Two factors have to be considered:

- What exactly was it which exploded? The most obvious candidates are (a) combustible dusts and (b) methane gas (or even a combination of both).
- What was the source of ignition that triggered the explosion?

4.4.1. What Was The Explosible Material?

The author agrees (in part) with the theory advanced by Professor Clifford Jones of Chester University who assisted the BBC's investigations in April 2025[4]. He considered that "***there might have been a localised area at the top of the silo or high concentration of dust and that would have been susceptible to a spark if one had entered it and any methane which was there by chance from a small leak, because they are known to occur, would make it all the more powerful***". However, as discussed in section 4.5 below, the author believes it is more likely that that methane was the primary source of the explosive atmosphere rather than combustible dust. That said, the presence of combustible dust (if present) would have exacerbated the explosion.

[3] HSE Prohibition Notice : Wessex Water 9 December 2020 – URL Link

[4] News Article, Martin Jones (BBC West Investigations) & Alon Aviram (BBC News) URL Link

4.4.2. What Was The Source Of Ignition?

1) A report published by the Bristol Cable stated that it had "***learned that the workers who were killed were using disk grinders on the silo, according to two sources with knowledge of the investigation***".[5]
   Activities using 'angle-grinders' or 'disc cutters' which give rise to sources of ignition are collectively termed 'hot work'.
2) The reference to 'hot work' within the HSE prohibition notice supports Bristol Cable's findings.
3) Whilst the HSE understandably remain tight-lipped about details of their criminal investigations and the exact cause of the incident, their scientists are not so shy. A report issued in 2023 states: "***There has been a recent history of catastrophic incidents in the UK in which the potential for flammable atmospheres in tanks, other than the digester, was overlooked, and where uncontrolled hot works caused explosions resulting in multiple deaths and serious injuries; one of the most severe of these included the explosion of a silo at Wessex Water, in December 2020, which resulted in four fatalities***".[6]
   The key words here are 'uncontrolled hot works' and 'flammable atmospheres'.
   - 'Hot works' reaffirms the notion that that the disc cutter was the source of ignition.
   - 'Flammable atmosphere' strongly suggests gas (i.e. methane) since the term 'combustible' would generally be the descriptor used for a dust explosion. Besides, the report majors on flammable gases only, with all the discussion being about methane and other gases. Dust is not mentioned once in this 12-page report, nor in a more recent HSE publication on the same topic[7]. This is perhaps something of an omission since digested sludge is often further treated by thermal and other processes in the preparation of biosolids for agricultural use where combustible dusts most certainly do present a significant risk of explosion.

4.4.3. Source of Ignition – Alternative Considerations

As discussed, it appears the team working on top of the silo was using a disc-cutter. The HSE will presumably have further information as to the tasks they were undertaking. If they had to cut through a pipe (e.g. to remove a valve or similar) where the pipe had a direct air connection to the interior of the silo, then the pipe would have contained methane and the heat/spark of the cutting process would have ignited it. If the task was to cut a hole in the roof of the silo then that would have ignited the gas as soon as the cutting wheel breached through the metal.

If they were using the disc-cutter for some other purpose not directly connected to the interior of the silo then this would imply that there was a leak of methane escaping from the silo into the air around them which was ignited by the cutting activity. Methane has no odour and the workers would only have been aware of its presence if they had been carrying a standard multi-sensor gas detector as used throughout the water industry. However, they would not have seen the need to do so unless a risk assessment (by others) had designated the silo top as a 'hazardous area'.

Since there were no survivors from the top of the silo the possibility cannot be ruled out, no matter how faint, that the disc-cutter was not in use at the moment of the explosion. It could have simply been a mobile phone or other non-intrinsically safe electrical device (see section 5.4.5 below). Again, they would only have been alerted to the fact that they should not take mobile phones or other electrical devices up with them if the silo top had been risk-assessed, correctly classified as a hazardous area and appropriate signage posted at the access point(s) to the silo. Brian Vickery was a highly experienced operator, fully aware of the dangers associated with such hazardous areas (e.g. atop the sludge digesters) and would have diligently complied with any such safety rules.

In terms of learning lessons for the future, it must not be assumed that it is only hot work which gives rise to such risks. For example, if someone had gone on top of the silo to disconnect pipework just using manual tools such as spanners and then used some electrical equipment such as a torch, lamp or mobile phone the same tragic outcome could have ensued. It is important that all such areas are properly designated and signs posted to warn of the danger.

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[5] Bristol Cable : New details revealed about fatal Avonmouth explosion at Wessex Water Plant – Alon Aviram, 11 Aug 2021 – URL Link
[6] Explosion safety in anaerobic digestion sites; where it can go wrong and guidance to avoid that happening – S Bergin et al, 2023 – URL Link
[7] Process safety at anaerobic digestion sites and its workplace impact: A rapid review – A Beswick etc al 2025 – URL Link

4.5. Plausible explanation for presence of methane in silo

It is likely that the methane had been generated in considerable quantity within the silo itself by the natural microbiological digestion processes. After all, we just have to look further back up the line to the source of the biosolids. These have been produced by the anaerobic digestion of sewage sludge. Sewage sludge contains a wide variety of microorganisms known as archaea (e.g. Methanosaeta, Methanosarcina etc) which, as the name suggests, produce methane gas in anaerobic (oxygen deficient) environments. These are known as 'methanogens'.

The addition of lime raises the pH to around 12 (very alkaline). Maintaining those conditions for a specified period of time kills the pathogens such as E. Coli and Salmonella. However, if those conditions are not met, then the pathogens and methanogens could pass on through into the silo still viable. Although normally killed off by oxygen, it is possible for methanogens to survive, protected by biofilms and deep in the biosolid where oxygen cannot penetrate. In case of inadequate lime treatment, organisms such as heterotrophic bacteria and archaea may also remain viable and, with the abundant supply of nutrient around them, can deplete oxygen which favours methanogen activity. There are several reasons why the specified conditions may not be met such as insufficient lime (target pH not achieved), insufficient contact time, non-uniform mixing (clumping). As a side issue, if lime treatment has not been sufficient to kill methanogens, then it is likely that the more resilient pathogens will also have survived. The implication of this being that sludge may have gone off for agricultural use in breach of the Sludge (Use in Agriculture) Regulations 1989.

It should be noted that an accumulation of methane gas may have built up over a prolonged period of time and, being one of the few gases that are lighter than air, would have accumulated in the top of the silo. In other words, any occurrences of lime-deficiency in the treatment process may not have immediately preceded the incident but could have taken place quite some time beforehand, gradually increasing methane levels. Anyone going up on top of the silos before 3rd December would have been unaware of a 'time-bomb' lurking inches beneath their feet.

4.6. Protective Measures for Silos

It is well known that silos containing organic material are prone to explosion. Over the years such incidents have occurred in flour mills, grain silos, sugar silos etc with devastating consequences including multiple fatalities.

As regards the treatment, drying and processing of sewage sludge, an article specific to the sewage treatment industry was published in August 2000 alerting the industry to the risks.[8] A number of preventive and protective measures are outlined. It concludes: "***Protection of the storage vessel against the damaging pressures associated with a dust explosion is usually best achieved by explosion relief venting, provided this can be discharged to a safe area***". The easiest, safest and most obvious protective measure is indeed to provide explosion relief panels such as those illustrated in figure 8 below:

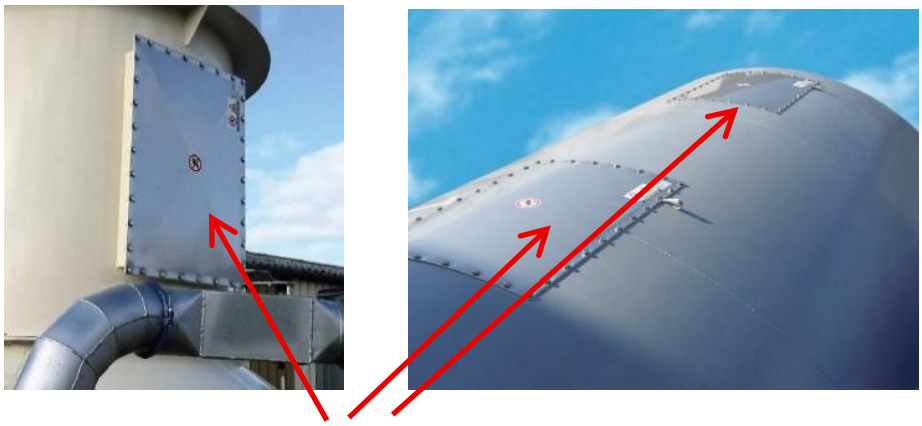

Fig 8: Examples of explosion relief panels fitted to silos[9]

[8] Safety measures up storage of sewage sludge, Process Engineering, Ian Barkinshw (Portasilo) – 22 Aug 2000 – URL Link

[9] Source of photos in fig 8: Filquip PTY Limited – URL Link

Explosion relief panels are designed such that when an explosion occurs these panels are the 'weakest link' and will blow out, allowing the explosion to vent to a place of safety. A convenient analogy would be that of a fuse in an electrical circuit such as the 3, 5, and 13 amp fuses we are familiar with for household appliances. In the event of a fault in the appliance or cabling causing a dangerous surge of electrical current, the fuse is the 'weakest link'. It will blow, breaking the circuit and thereby preventing overheating, equipment damage and fire.

As can be seen in figure 8, these panels are usually readily visible. On examination of all of the photographs and aerial videos of the Avonmouth incident, the author can see **no evidence of any such panels being fitted to the silos involved in the explosion** – either on the sides or on the top. It is unlikely that such panels would be shielded from view by virtue of being round the other side of the silos since this would vent inwards towards the conveyor systems and the adjacent building. The author is astonished at the apparent absence of such panels.

Other preventive/protective measures are theoretically possible that would not be visible from the outside, such as inertisation, powder suppression or containment (where the structure of the silo and all connected plant has to be designed to withstand the high pressures involved (up to 9barg).

The fact remains that if any of these measures were in place, properly maintained and working effectively, then the catastrophic explosion would not have occurred in the way that it did. HSE, of course, has had the benefit of making a close examination of the surviving silo which remained intact and they will know whether any panels were fitted.

4.7. Legal Framework and Standards applicable at time of construction

Long before the design and construction of the Avonmouth lime-treatment plant in 2004 the risks of explosion associated with sewage sludge processing were well known to the water industry. In 1987 a fatal explosion occurred in a sludge digester at a waste water treatment plant in Pennsylvania. This was triggered by the use of a non-explosion-proof electric light which ignited methane gas. This highlighted the need for improved safety standards for electrical equipment that is to be used in hazardous areas. We call this 'intrinsic safety'. It ensures that combustible dusts or flammable gases cannot reach any internal parts of electrical devices which may generate a spark or other source of ignition. It is important to note that the safety requirements are more stringent for atmospheres involving flammable gases than for combustible dusts. The significance of this will become clearer in section 5.4.5 below.

In 1994, a European Directive known as 'ATEX' (ATmosphères EXplosible) was published. This was a 'Product Directive' which set out requirements for the supply of equipment and protective systems intended for use in potentially explosive atmospheres.

Further official guidance was issued in 1998 with the publication of the standard BS-EN-1127-1 'Explosive Atmospheres – Explosion prevention and protection'. This set out the basic concepts and methodology for the safety management of flammable liquids, gases, vapours and combustible dusts. In particular, section 6.5.3 'Explosion relief' set out the principles involved with explosion vent panels and section 6.5.4 'Explosion suppression'. So the engineering requirements for plant handling potentially explosible materials were well-known and there can be no excuse for failing to implement them. Although not legally binding, the standard set out 'best practice' for workplace safety and could be taken into account by the HSE and the Courts when assessing an employer's general duty of care under the Health and Safety at Work etc Act 1974.

In 1999 the ATEX Directive for protection of workers from the risk of explosive atmospheres was introduced. This was a 'workplace' or 'user' directive. Again, this was not law in the UK but, as with all EU Directives pre-BREXIT, it required the UK Government (and all other member states) to implement its requirements within their national legislation. This was done, with the implementation of the Dangerous Substances and Explosive Atmospheres Regulations 2002.

So, by the time the sludge treatment facility and the two silos were installed in 2004/5, there were strict legal requirements to be met which, on the face of it, Wessex Water did not comply with. The Regulations were supported by very clear, unambiguous guidance published by HSE. In fact this document, known as 'L.134 DSEAR Design of plant, equipment and workplaces' was not just 'guidance' to be followed or ignored at a whim. Being an 'Approved Code of Practice' it has a special legal status as follows, stating "***If you are prosecuted for breach of health and safety law, and it is proved that you did not follow the relevant provisions of the Code, you will need to show that you have complied with the law in some other way or a Court will find you at fault*** ".

Paragraph 76 of the code sets out the measures necessary to mitigate the effects of an explosion (including explosion relief, suppression and pressure resistant plant). It reads "***Where there is a residual risk that an explosion could occur and cause injury, employers must ensure plant and equipment is provided with explosion protection measures to minimise that risk of injury***"

4.8. Risk Assessment Methodologies

Through the issue of the prohibition notice shortly after the explosion, HSE were clearly of the opinion that Wessex Water had failed to do a 'suitable and sufficient' risk assessment.

There are a number of ways by which a risk assessment can be done. The overall intention is to force employers to pause for a moment in their busy lives, simply think things through and ask themselves questions such as 'What hazards are my employees exposed to?', 'How can I best control those hazards to prevent them from hurting people?', 'Am I doing enough to control those risks and, if not, what more do I need to do?'.

However, when it comes to potentially explosive atmospheres the law is very much more explicit and prescriptive. DSEAR Regulation 5(2) makes it an absolute requirement that certain aspects must be considered in the risk assessment.

Some of the key requirements, relevant to these circumstances are as follows:

The risk assessment shall include consideration of:

- ***activities, such as maintenance, where there is the potential for a high level of risk;***
- ***the likelihood that an explosive atmosphere will occur and its persistence;***
- ***the likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective;***
- ***the scale of the anticipated effects of a fire or an explosion;***
- ***any places which are or can be connected via openings to places in which explosive atmospheres may occur.***

One advanced, but quite common risk assessment methodology used in the water industry is known as a 'HAZOP Study' (HAZard and OPerability study). This is often used where chemical processing, mixing and blending is involved. A multidisciplinary team with the right blend of experience and knowledge gather together to carefully consider the design of the plant, before it is even built.

They will examine the plans, starting from the point(s) where raw materials come into the system and work through the process to the final creation of the end product(s). At each step along the way (e.g. each valve, pipe, gauge etc) they will ask relevant questions using 'guide words' as prompts, such as 'What if there is too much', 'too little', 'no flow', 'reverse flow', 'inefficient mixing' etc. Then, if anyone identifies that one of those situations could present danger, they consider what needs to be done to detect and control the risk.

So, in this sludge treatment plant, relevant questions might have been asked 'What if there is no lime' (e.g. container/vessel empty, blockage or pump failure) or 'What if there is not enough lime'. The answer should be 'the pathogenic and methanogenic micro-organisms are not going to be completely killed off and could go on to form methane in the silos'. This would have led to suggestions for risk control options such as installing:

a) a level detector in the lime container – signal via telemetry to a control room if the level of lime in the tank/hopper falls below a certain level;
b) an alarm to signal if there is a fault with the lime-conveyance system which blends it with the sludge;
c) a gas monitor which will raise alerts if methane is detected inside the top of the silo, together with a means of safely purging any gas detected and, importantly:
d) explosion relief panels in the silos.

5. Later Installation of Additional Biosolids Silos

5.1. Installation

We now turn our attention to two further silos. Once again we rely on Google Earth historical imagery to establish that these were constructed between 14 April 2007 and 3 December 2009 (see figures 9 and 10 below):

Fig 9: Site for future sludge plant and 2 new silos

Fig 10: Site of new sludge treatment plant and 2 'new' silos

This section of the report raises questions about the safety of these two new aluminium silos with regard to possible explosion risks. The author wishes to emphasize that these are just that i.e. '**questions**' (not evidence of faults), but they deserve to be investigated and answered, if only to reassure staff working at the site..

The evidence discovered suggests **possible** safety issues which have probably already been addressed and resolved. One would certainly hope so, given that HSE must surely have been examining all aspects of the sludge processing arrangements. It is felt better to be on the safe side and to offer these issues up for consideration and follow-up if necessary. The last thing anyone wants to see is yet another tragedy.

These two aluminium silos were installed as a part of a new and innovative sludge treatment process which uses Acid Phase Digestion (APD) to maximise methane production. It is understood from a paper by Bungay et al[10] that the system produces high quality biosolids which meet the stringent quality standards required for agricultural use without the need for lime-treatment (with the pathogens being killed off during the APD process). This is further confirmed in a 'Water Projects' article[11] which relates to some remedial work whereby APD reactors had to be replaced. During this time, lime-treatment had to be resumed in order to kill off the pathogens and achieve suitable quality biosolids. Lime dosing stopped after the work was finished.

Question 1: Since the methanogens are active in digesters after the APD reactors and there is no lime treatment to kill them off before dewatering and storage in the 'new silos', can we be absolutely certain that they are killed/deactivated by some other means prior to storage? Otherwise they might produce methane in the silos. If we are just relying on aerobic conditions killing them off, are we confident that this is guaranteed 100% effective under all operational circumstances?

[10] Optimisation of the Advanced Digestion Plant at Avonmouth – S Bungay et al (15 Nov 2010) EBORC&E Conference – URL Link

[11] Water Projects Online - Avonmouth Acid Phase Digestion Remedials – N Shu (1 October 2017) – URL Link

5.2. New Silo Design Parameters

In 2013, an article was published in the 'Engineer Live' journal which described the design of these two new silos[12].

The author states: "***All the conditions needed for an explosion (except for the actual ignition source) exist within the Wessex Water silos, so Braby designed in explosion panels and calculated all other possible risks against ATEX regulations***" and "***Four explosion panels are also key to preventing explosions"***.

Figure 11 shows the proximity of these two new silos to the original green silos, one of which would later be involved in the fatal explosion:

Fig 11: Proximity of old and new biosolids silos
Source: Google Earth (31 December 2009)

It therefore seems that in 2007 Wessex Water, its engineers and scientists were fully cognisant of the fact that all the conditions needed for an explosion existed within biosolids silos and duly fitted four explosion relief panels to these silos.

Question 2: Given that all the conditions needed for an explosion existed within its biosolids silos, why did Wessex Water not appreciate that similar conditions most likely existed within the two original biosolids silos, located just 76 metres away and retrofit explosion relief panels to those silos?

Whilst the upstream processes were different (the original green silos being lime stabilisation and the new silver/aluminium solos being derived from acid-phase digestion and mesophilic anaerobic digestion), any fault in the treatment process which resulted in incomplete destruction of methanogens would result in an explosion risk.

Question 3: Would retrofitting explosion relief panels to those silos have prevented the incident which occurred on 3 Dec 2020?

The author is content to leave this for others to decide. It is a matter which should most properly be decided in Court.

[12] Engineer Live: Sewerage sludge materials handling package – Paul Boughton – 21 February 2013 – URL Link

5.3. Provision of Explosion Relief Panels in the 'New' Aluminium Silos

So far as is known, the new aluminium silos are still in use for biosolids today. Recent Google Earth imagery shows the silos were still present and operational last year, with tractors loading their trailers with biosolids.

Fig 12: Trailers being loaded with biosolids for agricultural use
Source: Google Earth (19 July 2024)

The Engineer Live article tells us that there are four explosion relief panels fitted to the roof of each silo. It is obvious that people have to go up onto the roofs of the silos from time to time. It can be seen from the photograph in the Engineer Live article that a staircase leads to the top of the silos, which are properly surrounded by guardrails.

Question 4: Has Wessex Water considered the risks associated with installing the panels into the roofs of the silos when it is foreseeable that personnel might be on top of the silos at the time of an explosion, as was the case in December 2020?

It isn't possible to identify the explosion panels from the photographs but it is assumed that the panels are fenced off in order to prevent a person standing on one, regardless of whether they are frangible or solid metal panels. Even just being close to the panels at such a time would be a considerable risk. There are some obvious benefits achieved by installing explosion relief panels into the roofs of silos since this maximises usable volume inside a silo and discharges the explosion vertically upwards. However, this has to be seen against potential safety risks.

Question 5: Is there a risk of the panels becoming airborne missiles in the event of an explosion?

This rather depends on the type of panel (frangible, bolt-release/tethered or hinged vents). In many types of panel the doors remain intact and if they should break loose would become a dangerous airborne missile.

How are the explosion relief panels restrained? Can we be absolutely certain that the bolts fixing the panels and/or tethers to the roof are robust enough to achieve this, particularly if the force of the explosion is greater than the panels (and silo) have been designed for? As discussed in section 5.4 below, the silos appear to have been designed and constructed only to withstand a dust explosion. Is there a possibility that, in the event of a methane explosion, the resulting pressure surge could cause the bolts to fail in shear or pull-out, turning the panel into a dangerous airborne missile, the bolts into shrapnel, and any restraining tethers into a potential whip hazard?

Question 6: Are the explosion relief panels protected against ice formation / freezing,

Explosion relief panels located on roofs are subject to environmental conditions which don't apply to panels located on the sidewalls of silos, at least not to the same extent. During winter they are vulnerable to icing from mist, dew, snow or accumulating rain which then freezes. Ice formation may inhibit proper opening of panels, increase sealing or adhesion forces, or even block hinge/friction movement. Ice loads themselves may add weight or alter dynamic behaviour of panels. These factors may result in the panel not blowing open in sufficient time to achieve the design standard of 0.7 bar g (see below), which could result in catastrophic failure of the silo.

5.4. A Design Flaw Presenting an Explosion Risk Today ?

5.4.1. The Issue

The Engineer Live article gives more details about the explosion relief panels. It is these details which are of concern:

"***Four explosion panels are also key to preventing explosions. Calculated on the volume of the silo and the explosivity of the material, the panels are built in to the roof of the aluminium silos to reduce the pressure to 0.7 bar g (Pred)*** [13]***. All components selected and fitted are ATEX certified and compliant to zone 20 internal and zone 22 external***."

In order to understand the concern, we need to understand the procedures for 'zoning' (having regard to the mentions of zone 20 and zone 22 above). The procedures for zoning were established by the ATEX 'Workplace' Directive 1999 (EU 1999/92/EC) and instituted into UK law by DSEAR 2002. The zoning criteria are shown in figure 13 below:

2. **Classification of hazardous places**

Hazardous places are classified in terms of zones on the basis of the frequency and duration of the occurrence of an explosive atmosphere.

The extent of the measures to be taken in accordance with Annex II, Part A, is determined by this classification.

Zone 0

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.

Zone 1

A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

Zone 2

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Zone 20

A place in which an explosive atmosphere in the form of a cloud of combustable dust in air is present continously, or for long periods or frequently.

Zone 21

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

Zone 22

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Fig 13: Classification of hazardous areas (EU Directive / DSEAR)

It should be noted that:

- zones 0, 1 and 2 relate to mixtures with air, of **flammable gases**, vapours or mists.
- Zones 20, 21 and 22 relate to clouds of **combustible dusts** in air

The fact that the design engineers installed explosion panels and other components to zones 20 and 22 is evidence that only the possibility of explosions due to combustible dusts was considered, not gases such as methane. We come back to the same discussion as in section 4.8 above in that, unless work activities and processes are properly risk-assessed and hazardous areas properly classified, then potentially dangerous conclusions may be drawn.

The author wishes to stress that this should not be taken to imply any fault on the part of the silo manufacturer (Braby, now Reyam). It is not reasonable to expect them to understand the intricate biochemical and microbiological processes involved with advanced sewage sludge treatment techniques. They are entitled to rely on the customer assessing risks correctly and advising them on the types of fire and explosion hazards which may arise during the operation and use of the silos they are being asked to supply. Indeed, Wessex Water may have a written risk assessment document from 2007 which concluded that there was no risk of a methane explosion whatsoever, given the nature of the material stored in the silos. We assume that the HSE will have investigated this aspect.

[13] The design standard of 0.7 bar g is established in the relevant EN standards. 'bar g' means 'gauge pressure'. 'Pred' (reduced explosion pressure) is the maximum pressure allowable which can be reached inside a vessel during a vented explosion.
Gauge pressure refers to the pressure differential between the inside of a vessel and the surrounding atmospheric pressure.
1 bar = atmospheric pressure at sea level. Therefore 0.7 bar g equates to 1.7 bar (at sea-level).

Question 7: What criteria were used to classify as 20 and 22? Have these been reviewed since 3 Dec 2020?

Question 8: Is there any provision for monitoring methane levels in the silos and/or ventilation to remove it?

5.4.2. The Implications (Explosion Relief Panels)

We now have to consider whether the explosion relief panels installed into these two new silos would be sufficient to withstand a methane explosion when the calculations on size etc have been based on a dust explosion. To do this we need to look at the relevant ATEX standards

- **Dust explosions** are covered by BS EN 14491:2012 'Dust explosion venting protective systems'. This provides methods to calculate parameters such as the required vent area, the vent panel strength, the reduced explosion pressure (Pred). Pred is the peak pressure that occurs after venting systems have operated as intended. This must be below the silo's 'design pressure limit' or catastrophic structural failure may occur.

  Prior to 2012, guidance was available via the American NFPA 68 (1998, 2002) which covered both dusts and gases in the one standard.

- **Gas/vapour explosions** are covered by BS EN 14994:2007 'Gas explosion venting protective systems' which is similar in principle to BS EN 14991, but for gases and vapours with different calculations and limits.

Gas explosion venting is more stringent than dust explosion venting because gas explosions (e.g. methane–air) typically propagate much faster than dust explosions, with much faster rates of pressure rise which can generate higher maximum explosion pressures.

EN 14994 (gas) typically requires larger vent areas than EN 14491 (dust) for the same vessel, but actual area also depends on vent panel design and the maximum reduced pressure (Pred) that is to be achieved.

It may be helpful to revisit the analogy mentioned in section 4.6 above of a fuse in an electrical circuit. If an appliance requires a 3 amp fuse but we insert a 13 amp fuse instead then, when a fault develops, the additional current allowed through the circuit before the fuse blows could result in a fire or damage to the appliance. When scaled up to fuses in a consumer unit of a domestic residence, the consequences of using too large a fuse could result in a house fire. It is essential that explosion relief panels are correctly rated for the environment in which they will operate.

If dust-rated panels are exposed to a methane explosion the flame front and pressure rise is very likely to exceed the panels' rated capacity. The panels may then rupture too late, producing much higher internal pressures which could result in structural failure of the silo and injury or death to persons nearby.

Hopefully though, with the increased level of attention paid to the sludge treatment facilities at Avonmouth by HSE following the fatal accident, these issues will have been recognised and mitigated by now. If not, then this matter should be investigated as a matter of urgency.

5.4.3. Construction and Structural Integrity of the Silos

Question 9: Is the structure of the silo strong enough to cope with a methane explosion

The author has no reason to doubt the integrity of the silos - he is not a structural engineer. Nevertheless, given the discussion in section 5.4.1 above (designed to withstand dust, rather than methane explosion) the question should be asked as to whether the structure is sufficiently robust to withstand a methane explosion. One imagines that aluminium would be more vulnerable to buckling, tearing and deformation than carbon-steel silos. The gauge (thickness) of the aluminium is not mentioned in the Engineering Live article, but refers to 'marine grade aluminium' which confers lots of useful properties relevant to the environment in which they are situated. However it is understood that this does not necessarily infer greater tensile strength compared with some other alloys. These are questions which need consideration by an independent expert in this field.

Other questions which should be considered:

- Are the 'roof-to-shell' junctions such as welds, lap joints or bolted flanges adequate for such an explosion? This appears to be what failed in the December 2020 explosion.
- Would provision of stiffener rings be appropriate e.g. if silo strength needs uprating to cope with a methane explosion. As can be seen from the image in the article (figure 14 below), none are currently fitted.
- Whether fixings of equipment attached to the roof of the silo have sufficient capacity to withstand a methane explosion or might these be weak points? Consideration should also be given to other fixings on the sides, beneath and inside the silo (e.g. thermocouples).

Fig 14: Aluminium silo at Avonmouth (photo from Engineer Live article)

5.4.4. Fire Suppression System

It is good to note that the designers recognised the self-heating nature of the biosolids product. They have installed temperature monitoring, and installed a fixed fire suppression system which will release a mixture of argon and nitrogen gas into the silo should excess temperature be detected. This should satisfactorily address the risk of spontaneous combustion (i.e. smouldering materials becoming the source of ignition which could set off an explosion if the atmosphere above it became explosible with dust or methane).

However, it must be clearly understood that in the event of methane being present and an external ignition source being applied (e.g. hot work), the fire-suppression system cannot deploy nearly fast enough to prevent or suppress an explosion. Therefore, the explosion-relief panels must be correctly rated, positioned, and maintained to ensure effective pressure relief in accordance with ATEX and relevant explosion protection standards.

5.4.5. Other Implications (Intrinsically Safe Electrical and Non-Electrical Equipment)

The apparent misclassification of the hazardous area zone leads to another problem. As discussed in section 4.7 above, electrical equipment that is to be used in hazardous areas has to be 'intrinsically safe'. This is to prevent such equipment being able to ignite combustible dusts or flammable gases/vapours.

The applicable standards are:

- The BS EN 60079 series of standards: Suffice it to say that different standards apply for equipment which is to be used in flammable gas/vapour atmospheres compared with explosible dusts – with the gas standards applying the more stringent technical constraints. Equipment rated only for dusts, but which are exposed to a flammable gas atmosphere could be the source of ignition which sets off an explosion.
- The BS EN ISO 80079 standard (parts 36 and 37): The EN 80079-36 standard sets out the basic methods and requirements for non-electrical equipment intended for use in explosive atmospheres. EN 80079-37 then specifies the constructional safety, measures for control of ignition sources, and testing for specific types of non-electrical equipment. Some examples of non-electrical equipment which may be found in, or interconnected with silos are:
  - Mechanical Conveying Equipment such as screw conveyors, bucket elevators, and belt conveyors used to move bulk materials into or out of the silo.
  - Bearings[14], Valves and Dampers, Level Indicators, agitators, mixers, gearboxes and couplings

If not already done, the electrical and non-electrical equipment installed in the silo and connected plant should be reviewed for adequacy in the event of a methane accumulation. Equipment which is suitable for use in explosive atmospheres will be marked with the 'Ex' hexagonal symbol as shown in figure 15 below.

Particular care should be taken when selecting equipment, having regard to the markings at the top of the label. A quick check as to whether equipment is suitable for both gas and dust environments will be to look along the line to the right of the hexagonal Ex sign where '**GD**' should be found. If it just reads '**D**' then it is unsuitable (and illegal/dangerous) to use in an environment where methane or other flammable gases may be present. The other 2 lines of text (shown adjacent to the CE mark {which would nowadays be the UKCA mark}) are also important. It is beyond the scope of this report to explain all these codes – competent advice should be sought.

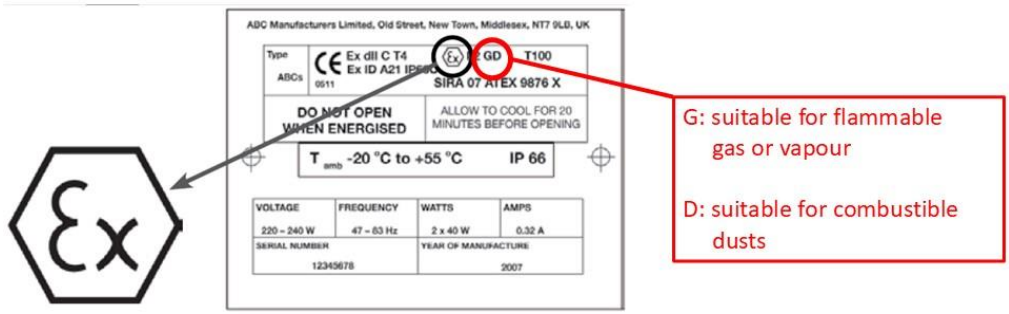

Fig 15: Typical ATEX equipment marking plate.
Source: Adapted from L.138 DSEAR, Approved Code of Practice and guidance (HSE)

In all of the above, hydrogen sulphide (H_2S) should also be considered. It is also a flammable gas and, of course, is highly toxic as well.

[14] The most common type of bearing used with conveyor systems is known as a Plummer block bearing. If management does not have a suitable and regular monitoring and maintenance/lubrication regime these can get extremely hot, become a source of ignition and ultimately may seize up and fuse to the shaft or housing. In this event they would most likely have to be cut out with a disc-cutter – a possible reason for the work party to have been on top of the silo? Simple and relatively inexpensive controls are available such as temperature and vibration monitors which can give early warning of such failures. One would hope that HSE will have investigated this possibility.

6. The Police and HSE Investigation

When there are fatalities at work the Police and HSE both commence their own investigations:

- The Police investigate whether any offences have been committed which may warrant prosecution of:
  - any organisation(s) under the Corporate Manslaughter and Corporate Homicide Act 2007; and/or
  - any individual(s) for Individual Gross Negligence Manslaughter.
- The HSE investigate whether any offences have been committed which may warrant prosecution of:
  - any organisation(s) under the Health and Safety at Work etc Act 1974 (HASAWA) and supporting Regulations such as DSEAR 2002; and/or
  - any individual(s) under sections 7, 36 or 37 of HASAWA

These investigations both started at the same time (December 2020). The Police/HSE will of course have collaborated, especially on technical matters. The Police investigation has supremacy. In July 2024 the Police and Crown Prosecution Service concluded that the threshold for a manslaughter prosecution had not been reached and stood down. The HSE continued their investigation and, in April 2025, told the BBC that their report would not be available before July 2025. Now, several months later, the families, friends and work colleagues still await answers.

Section 2.1 concluded by raising a rhetorical question as to whether HSE has done its job properly. In the author's opinion – certainly not. When a major incident such as this occurs, the Executive should deploy sufficient resources to enable a thorough investigation to be conducted in an efficient and timely manner, taking account of the fact that bereaved families need to have their questions answered in order to start getting some closure.

As regards the thoroughness with which HSE has conducted its investigation and identified all the issues described in this report we shall only know once they produce their own report into the incident.

It is quite understandable that any such report would be withheld until the criminal prosecution is brought to Court. However this really should not take 5 years to bring about. Not only is it awful for the bereaved families and friends to have to wait for so long, there are also be individuals in Wessex Water who may have to provide evidence in defence, for whom the wait must be extremely stressful. The same may apply to the Lord-Lieutenant of Somerset, Mohammed Saddiq who was General Manager of the Avonmouth site and closely involved in the management of sludge treatment operations.

Whilst some allowance has to be made for the fact that the incident occurred during the second wave of the Covid-19 pandemic, the fact that HSE is dragging this matter out for so long is quite unacceptable. It has only taken the author a couple of weeks to ascertain the basic facts outlined in this report, without even visiting the site and just relying on internet resources. It is incomprehensible as to why it is taking the Executive so long to draw these painful matters to a satisfactory conclusion. They have access to experts, witnesses and physical examination of the damaged silo and its undamaged neighbour. In a nutshell, **if** there were no explosion relief panels in the solo then it is 'Quad Erat Demonstrandum', QED – in layman's terms 'slam-dunk'!

In July 2024 the HSE Principal Inspector confirmed in a press statement that they had been part of the inquiry from the outset. Incredibly, he then went on to say that they were still trying to "establish if there had been any breaches of health and safety law" – the important word here is "**if**". In effect he was saying that despite having been investigating for almost 4 years, they still hadn't managed to discover whether any laws had been broken! This calls into question whether this once highly-respected regulatory organisation is still fit for purpose. This view is amplified by the fact that HSE has abrogated its statutory duty by knowingly permitting healthcare employers to provide doctors, nurses and other healthcare workers with surgical masks during the COVID-19 pandemic while caring for infectious patients. These masks have all the protective properties of a chocolate fireguard against an airborne disease such as this (ditto flu, RSV and similar).

7. Conclusion

A news reporter, in his report on the day of the Avonmouth explosion, remarked: "***It is thought there was little anybody could do to prevent such a tragic outcome***". Hopefully this report will have explained that there was plenty that could (and should) have been done to prevent the loss of four lives.